Prof. PhD Konstantin Dimitrov,
MSc. Ass. Ognen Dimitrov

DECARBONISATION OF THE ELECTRICITY GENERATION

Can the Republic of Macedonia make a full switch in its electricity generation process from fossil fuels to renewables by 2050?

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Authors:
Prof. PhD Konstantin Dimitrov,
MSc. Ass. Ognen Dimitrov

Translation from Macedonian:
Makedonka Dimitrova
Matthias Meyer

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Matthias Meyer

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Can the Republic of Macedonia make a full switch in its electricity generation process from fossil fuels to renewables by 2050?

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April 2016

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1. INTRODUCTION AND GOALS

This document will provide think tanks and experts involved in this field with a basis to continue their engagement towards providing an input and to create a favourable environment for the ultimate goal - Macedonia's **decarbonisation**[1] vision until 2050.

In the beginning, the process shall involve few enthusiasts with analytical skills. Later on, the process will require the involvement and the contribution of a relatively wider expert audience through the organisation of promotional round tables. And finally, why not also be adopted and embedded by a political party as an element of its platform for the future development of Macedonia?

Through such a transparent process, the preparation for this vision will be shaped as a representative document which shall further be used as a starting point for future activities, such as the preparation of scenarios and the development of models for the decarbonisation of the electricity sector until 2050, as well as the whole energy sector i.e. the economy in general.

Is there a reason to commit to the preparation of such a vision?

There are many reasons leading to a serious approach towards the initiation of this process within our society. By doing this, Macedonia would intensify its involvement in the worldwide process to 'save the planet from the influence of climate change' according to its possibilities. Despite the fact that our contribution to climate change is incomparably minor compared to highly industrialised countries, it is even more important to participate in the process coupled with the expected influence on a local level.

However, the basic reason to approach the reduction of fossil fuels usage (decarbonisation process) is, above all, initiated by our own domestic needs. Macedonia is a country dependent on imports when it comes to fuel supply. The import of fuels (liquid and gaseous fuels, quality coal) averages 48%, or almost half of total supply.

1 The word "de-carbonization" means "energy production excluding carbon combustion".

Macedonia is import dependent and has limited reserves. According to the strategic documents of Macedonia, coal represents the basic fuel for electricity generation today and in the future until 2035. What will happen afterwards?

This means that we do not have enough domestic supplies to meet our individual needs and in addition we are importing 50% of the required fuels.

Is this not a JUSTIFIED REASON to start thinking about and PREPARING for what we shall be facing in the period after 2050?

We have succeeded in satisfying a part of the electrical power needs given the limited resources. More precisely, about 30% of the electricity is imported. The domestic generation of electrical power is meeting the needs of 95% of the low voltage user's grid, where households represent the majority of consumers. However, in accordance with the conditions prevailing in the liberal electricity market, the industry has to meet its energy needs through imports! If this is the current situation, what will happen tomorrow or after 2035? This is another reason to seriously approach the preparation of a more favourable environment within society for moving towards a carbon-free society!

If Macedonia promotes the production of electricity from renewable sources, it will be free of fuel imports required for its industry, as well as free from electricity imports, which are to be imported according to documents related to the energy sector. Could this represent an act of opportunistic goal or is it rather an economic and even political necessity?

The decline of fuel and electricity imports would result in a higher level of sovereignty for Macedonia, meaning that there would be no more opportunities to exert political pressure based on the dependency of imported energy (in all its forms).

And last but not least, we also have to emphasise the need of our society to seriously commit to the reduction of local pollution. One of the elements of the "greenhouse" effect and climate change are carbon dioxide emissions. The impact of climate change is evident here, but locally, we could contribute a lot to protect against drought, torrential rains, and strong winds. Further, we could reduce the local pollution directly affecting the health of employees and, even more important, the health of our children. Try to estimate the improvements in health protection if we eliminate thousands of tons of ash being discharged into the atmosphere from coal-fired thermal power plants. And one of the dominant sectors contributing most to greenhouse gas emissions is the electricity production sector, keeping in mind that the main greenhouse gases are released in the process of the combustion of fossil fuels, especially those involving coal and liquid fuels. Could we neglect the emissions of sulphur dioxide, which, together with nitrogen oxides, contribute to ‘acid rain’ and ‘photo pollution’? What about their influence on the soil and on people’s health? Yet, this is one more reason for the Macedonian society to approach the development of a society free of (or with reduced) fossil fuels seriously.

Is this idea/vision a utopia or it is well grounded?

Are there enough potential renewable resources in Macedonia for electricity generation?	YES!
Is it technically feasible to generate electricity in Macedonia solely from renewable resources?	YES!
Will the process positively influence Macedonia to stop fuel and electricity imports?	YES!
Will the environmental pollution be reduced?	YES!
Will this mean that Macedonia would join the program for climate change reduction to protect the Earth from global warming?	YES!
Is this goal an easy one to accomplish?	NO!
Are significant financial investments required?	YES!
Can the results be accomplished in a short period of time?	NO!

Which are the necessary requirements to reach the desired goal?

Besides the numerous technical and administrative requirements, there is a need for the following:

- Political will!
- Bringing together a pool of intellectual potential!
- Operational institutional connectedness!
- Focused joint activities of the academic, scientific and research institutions, and the industry!
- Financial resources!

WE AIM FOR THE STARS.
IF WE DO NOT REACH THEM,
WE WILL BE ON THE RIGHT
TRACK!

2. ENERGY AND ECOLOGY DEVELOPMENT POLICY BY 2050

By the end of 2015, humanity has bravely and ambitiously entered the energy era of the 21st century, adopting by consensus a balanced agreement to stop climate change and maintain the rise of the average global temperature below 2 degrees Celsius compared to the temperature of pre-industrial times. As one of the potential signatories of future agreements, Macedonia faces many challenges but also threats and opportunities.

The current strategic plans to use its own resources, especially renewable energy resources, have not been fully realised due to the large number of obstacles that these projects and initiatives are faced with.

Those barriers could be of economic, technical, environmental, legislative and social character. Some of them occur as a result of poorly organised public consultations related to topics the public should have been informed about and to which it should have adapted. This requirement is closely connected to our goal of joining the European Union, is partly a result of technological progress and development and, moreover, for the sake of mitigating climate change.

Energy Union Choices[2] reflects on the multi-layered complexity of the energy transition towards integrated energy systems. Moreover, the initiative points out the importance of shared assumptions and a shared understanding of the challenges that will enable us to make the right choices. Further, to accelerate the transition path in an acceptable, sustainable and safe manner - the geopolitics of energy transition. This group advocates the unification of different views on both the challenges and the solutions in a transparent, inclusive and non-confrontational manner. Ultimately, only a common understanding of the context, the challenges and the solutions can support Europe on its way to progress.

„Climate change represents an urgent and potentially irreversible threat to human societies and the planet and that is the reason for broad cooperation

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2 Energy Union Choices is an initiative of the European Climate Foundation, in close partnership with E3G, Cambridge Institute for Sustainable Leadership, Agora Energiewende, Regulatory Assistance Project (RAP) and WWF, as well as other partners in the network ECF; http://www.energyunionchoices.eu/.

among all of the countries and their participation in an effective and immediate reaction at international level to be able to rapidly reduce the global emissions of the greenhouse gases. In addition, we should recognise the fact for significant reduction of the global emissions aiming to achieve the ultimate objective of the Convention while emphasising the need for urgency in tackling climate change issues”[3]

Besides the documents emerging from the Paris Convention, there are numerous analyses prepared and presented by IRENA (International Renewable Energy Agency), especially the publication „Renewable Energy Benefits: Measuring the Economics”.[4] The gains from the utilisation of the renewable resources offer dual purpose solution i.e. to enable economic growth as well as to decarbonise the economy across the world.

The increased dissemination of renewable energy sources will stimulate economic growth, create new employment opportunities, improve the welfare of people and contribute to safe climate conditions in the future. The technological advancements in the area of renewable energy sources and the increased financial competitiveness will strengthen the business sectors tightly connected to renewable energy sources. It could also provide new opportunities for countries that are faced with the transformation of their energy systems. There is evidence that the gains from an increased utilisation of renewable energy exceed the cost competitiveness.

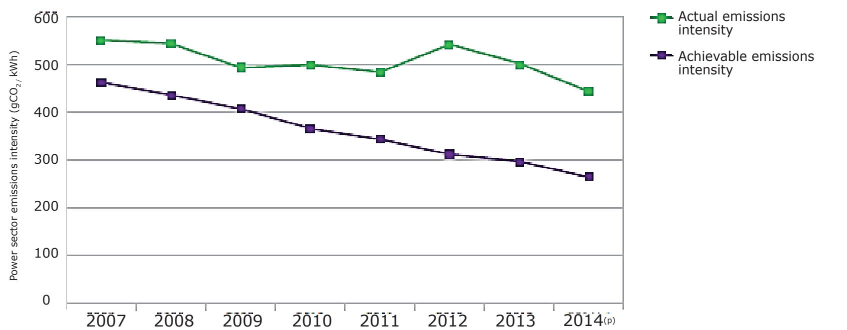
The increase in the construction of renewable infrastructure could meet the energy needs of a constantly growing population, stimulate development and promote welfare, given the proportional reduction of greenhouse gas emissions as well as an increase in the productivity of the natural resources. This also provides empirical evidence that economic growth and environmental protection are fully compatible. In addition, it also negates the traditional view that one compromises the other as outdated and wrong.

3 United Nations FCCC/CP/2015/L.9 Distr.: Limited 12 December 2015 Pariz, Adoption Of The Paris Agreement.

4 IRENA (2016), ‘Renewable Energy Benefits: Measuring The Economics’. IRENA, Abu Dhabi.

The Government of the UK has submitted to Parliament evidence based advice during a rising number of consultative meetings on the topic of the decarbonisation of electricity production in order to successfully implement this particular task. The Reports identify that in the period between 2009 and 2014, emissions in the energy sector decreased by an average of 4% per year, with a recorded highest stake of 18% in 2014. The decarbonisation of the energy sector is of crucial importance to the economy, given the potential of electric energy to result in low-carbon emissions across other sectors as well. The Energy Law, passed in 2013, has enabled reforms in the electricity market to support the transition towards a low carbon energy sector. The first contracts to support the energy generation characterised by low-carbon emissions were signed under the umbrella of the Electricity Market Reform and have further enabled the good progress of emission reductions towards 2020. The Committee concluded that this was an important step forward but that a high degree of uncertainty, regarding the further investments planned for the period beyond 2020, remains. Also, they suggested to Parliament certain measures aiming at the various types of renewable energy sources.[5] The reasons for this activism were to realise achievable reductions in the intensity of the emissions, as compared to achieve ones as shown in Figure 2.1.

Achievable emission intensity in the UK (2007-2014)



Source: CCC calculations based on DECC Energy Trends (March 2015).
Note: Achievable emissions intensity is the minimum average emissions intensity that could be achieved in a year, given the installed capacity of power sector technologies, electricity demand and the demand profile of that demand. Emissions intensity is UK based useable generation, i.e. excluding losses. In 2015 we revised the Achievable Emissions Intensity methodology to include emissions of 200 gCO_2/kWh for electricity generation from biomass to reflect sustainability concerns, which changes values in all previous years (this is not included in actual emissions intensity).

Figure 2.1. Achievable emission intensity in the UK

5 A balanced response to the risks of dangerous climate change; Independent, evidence-based advice to the UK Government and Parliament, Committee on Climate Change; https://www.theccc.org.uk/charts-data/ukemissions-by-sector/power/.

The ambitions set by the Committee for the period until 2030 are impressive. The process envisions two scenarios for the reduction of expected greenhouse gas emissions by 50 g/kWh and 100 g/kWh (Figure 2.2.). As a result of the utilisation of renewable energy sources the reduction of greenhouse gas emissions is significant, starting at a level of 120 MtCO2 and dropping to 40 MtCO2, according to conservative calculations.

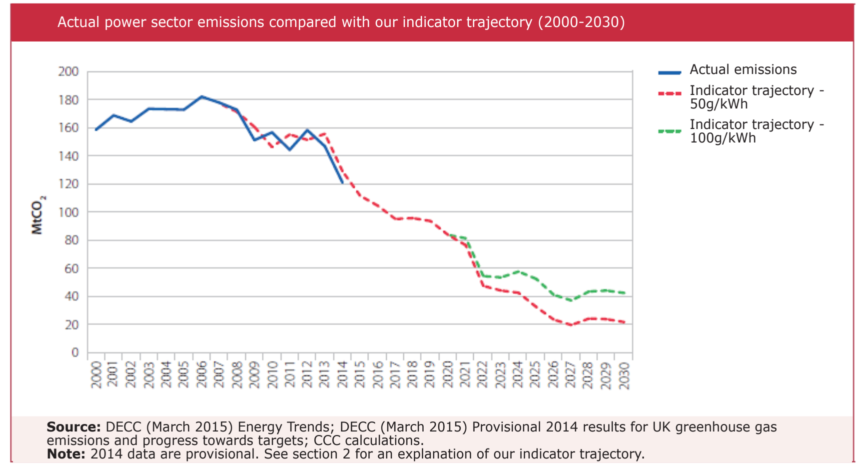


Figure 2.2. Assumptions for expected intensity reductions of the greenhouse emission from the power sector

3. DEFINING THE ENERGY NEEDS

The main features of the energy sector are defining the most important issues that Macedonia faces in this area. Those are: unfavourable availability of raw materials based on lignite, which is characterised by a low energy value; high dependence on imported energy fuels (50%); relatively outdated equipment and technology for electricity generation, causing inefficient production coupled with high energy intensity.

The above-mentioned problems are burdened by the need for electrical power imports for the entities that purchase the electricity on the free trade market because it is not produced in Macedonia.

Because of the unfavourable relationship between the price of electricity on the free trade market and the price of energy fuels used in the electricity generation process (light oil and natural gas), the Thermal Power Plant Negotino with an installed capacity of 210 MW (heavy oil fuel) is not in function. Due to the unfavourable price of the natural gas, neither are the Te-To Skopje (245 MW) and the KOGEL Sever (30 MW), although both plants are installed with modern technology with a high degree of efficiency.

Four sectors in Macedonia are considered dominant energy consumers: the industry, the transportation sector, households and other sectors (tertiary sector), while the agricultural sector and the final non-energy consumption is within the boundaries of statistical error. The final energy consumption share of the different sectors is shown in Figure 3.1.

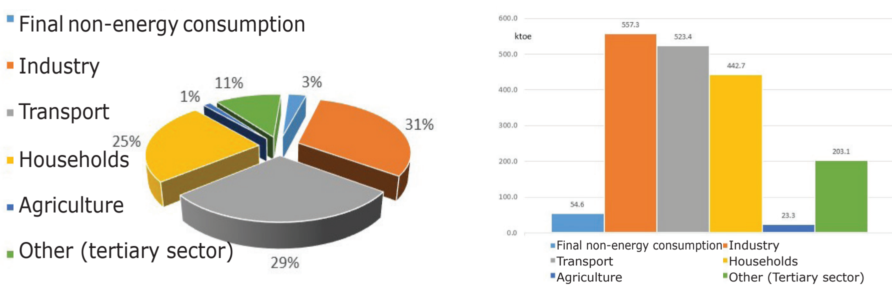


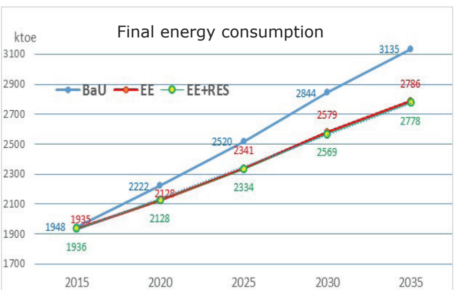
Figure 3.1. Final energy consumption by sectors

The Strategy for Energy Development in the Republic of Macedonia until 2035 identifies and develops three scenarios for defining energy needs. In particular, the Business as Usual Scenario (BaU), the Scenario with Energy Efficiency Measures (EE) and the Scenario with Energy Efficiency Measures and Renewable (EE & RES).

It is projected (within the defined scenarios) that the final energy consumption in the analysed period will increase at an average annual rate of 2.2%, 1.7% and 1.7%, respectively. In the three scenarios, the total energy needs will increase at an average annual rate of 1.1%, 0.6% and 0.5%, respectively. The Strategy expects that the Mining Energy Complex Bitola will remain a major producer of electricity during the lifespan of the equipment and until the exhaustion of the coal mines.

The final energy consumption in 2035 is expected to amount to 3135 ktoe (BAU). With the expected implementation of energy efficiency measures, the projected final energy consumption amounts to 2786 ktoe (EE) i.e. 11% less than in the baseline scenario.

Figure 3.2. shows the projections for final energy consumption by 2035 according to the Strategy.



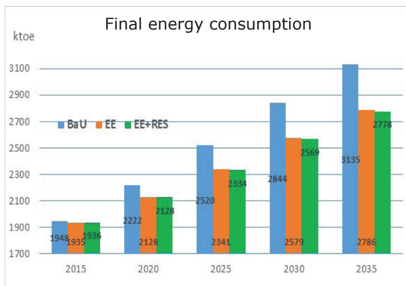


Figure 3.2. Projections for final energy consumption tendencies

The shares of the renewable energy sources (biomass, solar and geothermal) in meeting the total energy needs without the share of the hydropower potential that is part of the electricity production are as follows (Figure 3.3.).

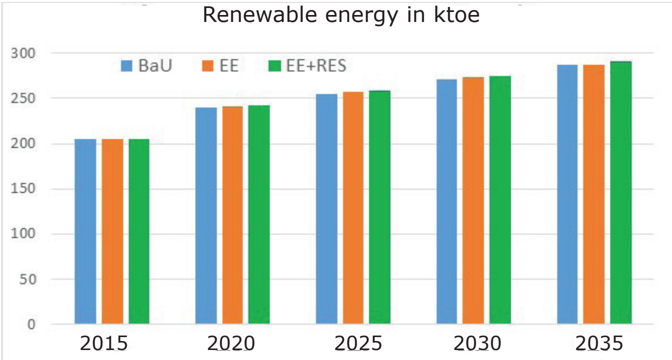


Figure 3.3. Shares of biomass, solar and geothermal energy in final energy consumption

In cases when the researcher seeks to project a tendency it is much easier to do it for a period of a few decades. However, it is very difficult to do a fairly good projection that will coincide with the likely reality for a period stretching over 3 to 5 years. In these cases, we proceed with proven conservative approaches including the following elements: an analysis of neighbouring countries' projections, the history of consumption tendencies in previous years, taking into account trends stipulated in the strategic documents for the period up to 2035, as well as other indicators available through the Statistical Office.

Four scenarios were projected and the results are shown in Figure 3.4.

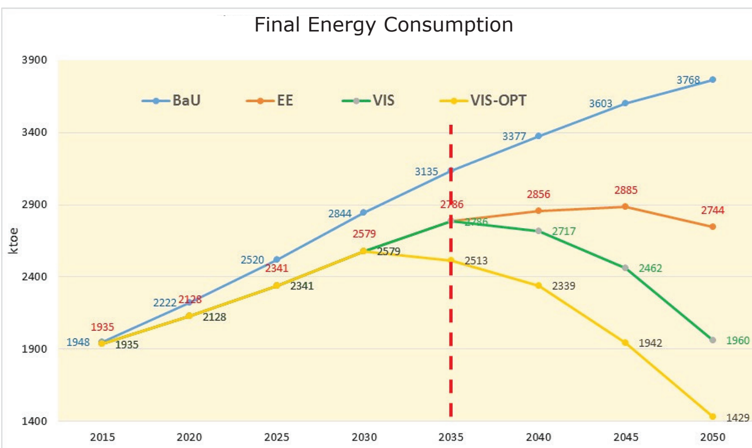


Figure 3.4. Projections of final energy consumption by 2050

Three of the scenarios are fully compliant with the projections set forth in the Strategy for Energy Development until 2035, marked as „BaU" - Business as usual, „EE" - scenario with energy efficiency measures, and „VIS" - scenario with a vision that energy consumption will be equal to the consumption recorded in 2015. The fourth scenario „deviates" the standard „EE" scenario from the Strategy commencing in 2030, representing a quite optimistic setting. It is therefore referred to as an optimistic vision - „VIS-OPT", with the projected final energy consumption being at a level 2.6 times lower level than the basic scenario; 1.9 times lower compared to the „EE" scenario and 1.4 times lower within the scenario „VIS".

Taking into consideration the assumptions adopted in the Strategy, the forecasts of energy consumption under the baseline scenario indicate a drop in the energy consumption in comparison to the consumption trend until 2035. The Strategy stipulates that all plants planned for construction will become operational as defined in the document. The main conclusion is that the share of renewable energy sources, although having increased their share due to low initial absolute values, but even with doubled values, will result in a low impact of only 10%, while hydropower has been excluded from the calculations.

Considerably higher interventions were made in the „EE" scenario which foresees that the same level of consumption will be achieved in 2050 as projected for 2035.

However, the vision of energy consumption as projected in the scenario „VIS" stipulates that the final consumption of energy in 2050 will reach the same level of consumption as in 2015. Under this scenario, the implementation of the energy efficiency measures is foreseen; a higher volume of domestic energy needs has to be met by dispersed small production capacities with emphasis on industry needs as well the continuously increasing share of households.

Is this approach realistic or utopian? There are a few indicators that contribute to this conclusion:

- An increase of the Macedonian GDP is projected;
- An increase in the living standard of the population is projected;
- By 2030, the energy consumption will increase due to a higher living standard and the need to improve the living conditions of all residents i.e. to achieve conditions for heating of all rooms of a household and not just of one or a couple of rooms;
- At the same time, new appliances will appear on the market that will considerably reduce electricity consumption;
- The price of electricity will increase;

- The new buildings will not burden the energy consumption of the country if they operate according to the EU Directives for the energy performance of buildings, especially given the requirement of the buildings to be built as „nearly zero" energy consumption buildings after 2020;
- There will be more installations such as heat pumps, consuming 1 kilowatt of energy and providing 4 to 5 kilowatts within the conditioned space;
- The situation of energy consumption in the industrial sector will dramatically change towards decreased consumption due to the suspension of certain smelters as a result of outdated equipment, lack of raw materials, etc;
- Purchase of modern technological equipment with low specific energy consumption per product and with little impact on the environmental pollution. Taxes for the polluters! Changing the habits of the consumers;
- Centralised production of transformed energy for satisfying users' needs with very high efficiency levels and little environmental pollution.

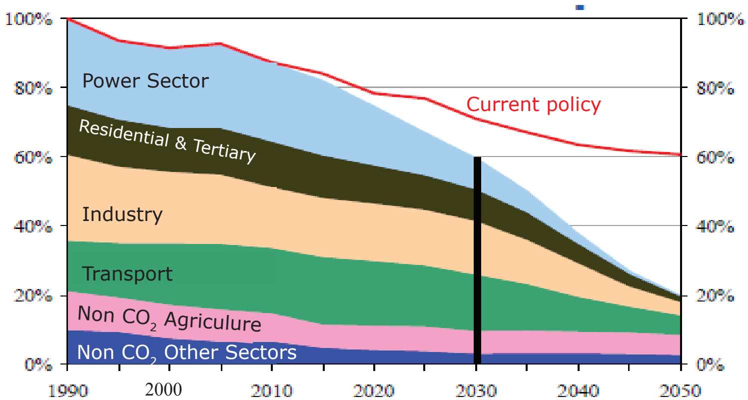


Figure 3.5. Projections of final energy by year 2050

Source: The hottest topics in the energy research, Prof.dr.sc. Neven Duić, 6th EPMES Workshop, March, 2016, Skopje

If you „look around" at what is happening or what is expected to occur in the environment, it can be concluded that the presented projections are not as visionary but are very conservative, pragmatic, or in simple words „alarming" projections. Figure 3.5. shows the projections for the expected developments of final production. This forecast (the literature offers more scenarios) shows that in 2020, energy consumption will be reduced by 20% compared to the baseline year 1990, which is considered as an initial year in the forecasting procedure. All of the above mentioned are entirely consistent with the EU Strategy 20-20-20. If we compare the expected consumption in 2050 with that in 1990 and the projected one for 2020, we could come to the following conclusions:

Unless we undertake additional measures to further invest in energy efficiency and renewable energy sources, the expected final consumption will be reduced to 60% compared to 1990, or be 1.33 times lower than the one for 2020. However, if we commit to serious efforts in implementing the policy for the decarbonisation of society, the final energy consumption will be only 20% compared to the baseline forecasting year!

This was the reason to add a fourth scenario and an optimistic vision – „VIS-OPT". Here, the final consumption is 1.37 times lower compared to the previous scenario „VIS" but still far below the forecasts and expectations of the EU.

4. IDENTIFICATION OF THE ELECTRICITY REQUIREMENTS

The basic electricity needs are met by the electricity generation from thermal power plants (dominantly utilising coal) and partial generation from co-generation plants (with a tendency of reduced production due to unfavorable pricing of natural gas and electricity), hydro power plants (big and small) whose power generation depends on the hydrological conditions, as well as through electricity imports, which are continuously increasing (Figure 4.1.).

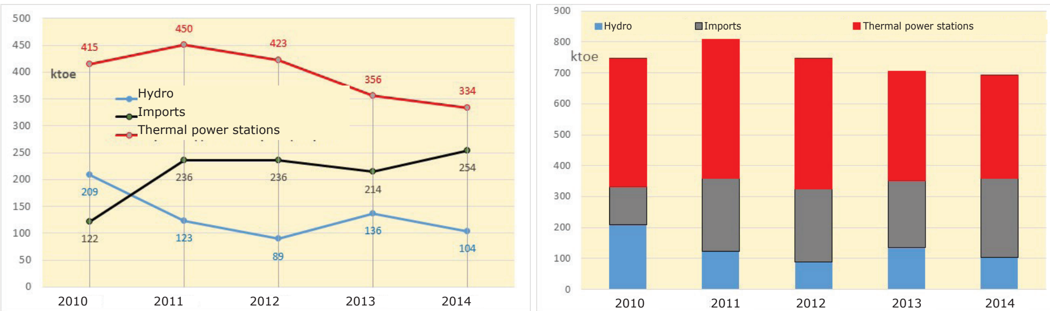


Figure 4.1. Meeting the needs for electricity from domestic production and import

Production capacities as provided by the following production facilities:

Type of power plant	Capacity (MW)
Thermal Power Plants (coal, light liquid fuel, gas)	1314
Hydro Power Plants (small and big)	636
Wind Power Plants	36.8
Photovoltaic Systems	16.7
Biogas	4
Total installed capacity	2007.5

The consumption trend of the available electrical power at the consumer level where the losses of transmission and distribution are calculated is shown in Figure 4.2.

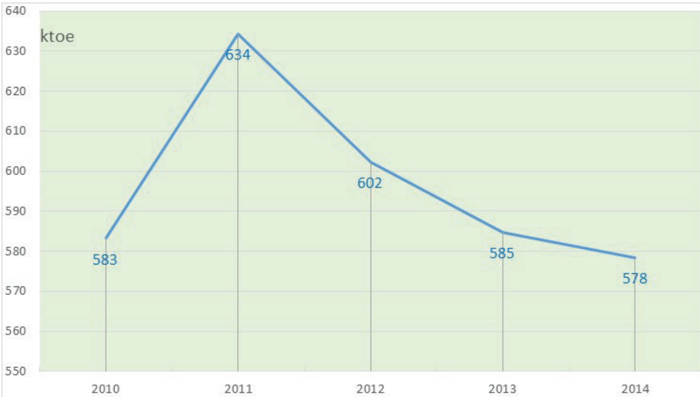


Figure 4.2. Available electrical energy for final consumption

Basic electricity consumption is monitored in three sectors: industry, households and other sectors (commercial and public buildings, tertiary sector). The electricity consumption by sectors is shown in Figure 4.3.

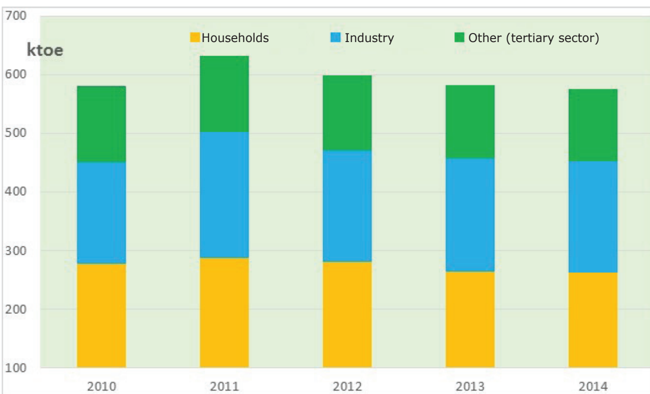


Figure 4.3. Electricity consumption by sectors

The first conclusion is that the electrical power consumption in Macedonia HAS DECREASED since 2011! A few reasons are contributing to this falling tendency, such as the price of electricity, higher awareness for energy management among the population (elimination of wasteful electricity consumption – habit change), as well as the utilisation of energy efficiency measures resulting in an increased use of solar thermal collectors instead of electrical boilers. This document will not provide any further deeper analysis of the matter as it is not the objective of this document.

According to the strategic documents, the assumptions for the share of the renewable energy sources in the electrical power generation are the following (Figure 4.4.):

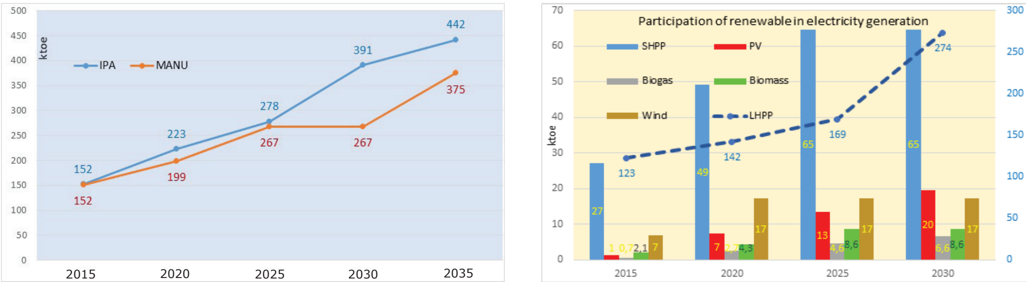


Figure 4.4. Share of the renewable energy resources in the electrical power generation according to the Strategy (MASA and IPA) and the Action Plan for RES

It is noticeable that there is a high share of hydro energy (big hydropower plants) in electricity production while the share of photovoltaic power systems is low.

The Strategy stipulates an ongoing increase in electricity consumption in the period up to 2035, especially in the industry sector (Figure 4.5.). And the energy demand among users is expected to reach 786 ktoe by 2035, according to the Business as usual - BAU scenario; or by 710 ktoe, according to the scenario with the implementation of energy efficiency measures.

Figure 4.5. Projections for electrical power needs by 2035

In relation to the discussion of the above mentioned point 3, where we have defined the total energy needs by 2050, a similar assumption was developed related to the expected increase of the energy consumption by 2050.

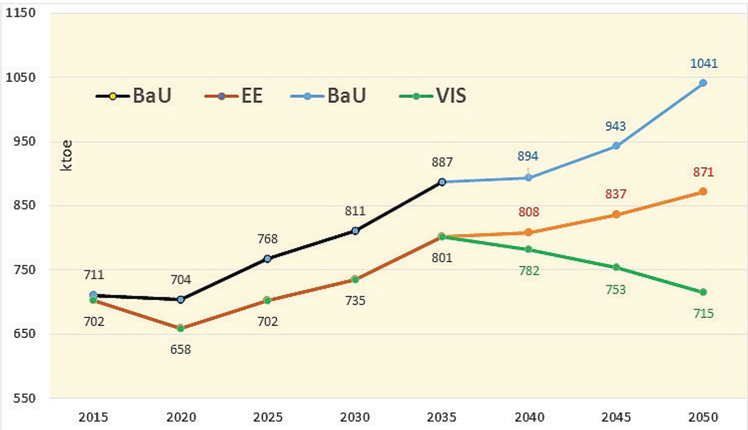


Figure 4.6. Projection for electrical energy needs at the final consumers by 2050

The baseline scenario envisages the delayed increase in the consumption of electricity but with full respect for the basic trend identified in the Strategy. The part referring to the scenario with increased energy efficiency measures has retained a proportion as projected in the Strategy. The scenario VIS uses data provided in the Strategy up to 2035. However, it further projects a greater reduction of electricity consumption in proportion to the expectations for the total reduction of energy consumption across all sectors of society. The extent to which this projection is visionary is yet to be identified, although we consider it as quite conservative i.e. realistic. In the following period of 35 years we are expecting that electricity consumption will remain at the same level as in 2015.

5. RENEWABLE ENERGY SOURCES POTENTIAL

In defining the potential of a particular fuel type there are several criteria to consider which are: theoretical possibility, technical availability and economic feasibility. Thus the limits of available technical and economically justifiable potential of any type of fuel are of elastic boundaries, which may over time change. New technologies are being innovated, new materials are being used and what was not feasible ten years ago today turns into routine. The same applies to the cost of equipment, which is economically justifiable when compared to the cost of the required power, political influence and environmental protection.

For this reason, we take into consideration available technical potential according to today's level of technological development. In other words, the economic category or the value of the investment is of secondary interest.

There is a need to answer the question - whether Macedonia has the available technical potential of renewable energy sources, which will fully meet the electricity needs by 2050 and later on (or in parallel to) the total energy needs of the society.

As stipulated in the beginning, the answer is positive.

YES, Macedonia has enough available potential to meet its needs for electricity from renewable energy resources.

Attention is retained in regards to the three major renewable energy sources, in particular the hydro energy at large and small hydropower plants, wind power and solar energy. The share of the biomass is to serve as a support, and just a complementary replenishment of the system for the production of electricity. The reason is that in the process of biomass utilisation, carbon is combusted producing carbon dioxide. However, it is acknowledged worldwide that this type of environmental pollution is compensated for by the growth of biomass, a process in which in the biomass absorbs the carbon dioxide from the environment in the same way it is generated during combustion. In the future, biomass plants could be used to cover needs when required and when lacking electricity generated from renewable energy sources.

The hydro potential in Macedonia is identified by the following parameters:

	Installed capacity	Generated energy	
	MW	GWh	ktoe
Large hydro power plants	960	5524	475
Small hydro power plants	70	175	15
Total	1030	5699	490

The hydro potential of the Vardar basin dominates with an available potential of about 4270 GWh, followed by the potential of the basin of the river Black Drim of about 880 GWh, and finally the summed up potential of the small basins is estimated at about 440 GWh. Thus, total hydro potential ranges from 5500 - 5600 GWh.

Expected Wind Power Plant Potential

	Installed capacity	Generated energy	
	MW	GWh	ktoe
Wind power plants	600	1320	113

Macedonian hydropower potential is dominated by a qualitative step towards the construction of wind power plants i.e. the Wind Park in Bogdanci. The ratio of electricity produced from renewable sources in 2015, in months, is shown in Figure 5.1.

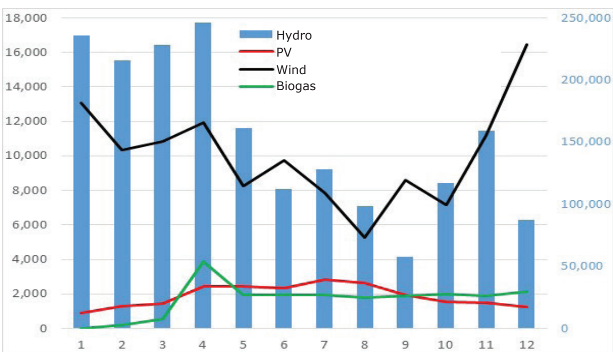


Figure 5.1. Electricity production from renewable energy sources in 2015

Solar Energy Potential

In determining the potential for solar energy, two elements are important: energy gained from solar radiation from a flat surface under the local conditions in Macedonia and the availability of surfaces for this purpose.

It is recognised that in Macedonia, due to its geographical location, there are good conditions for utilisation of solar energy. The potential of solar energy throughout one calendar year, measured at two different locations, is shown below.

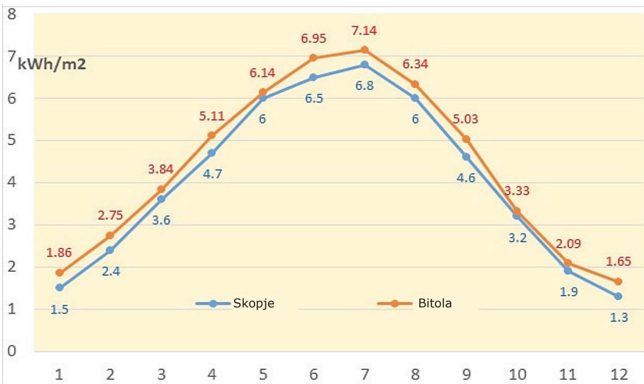


Figure 5.2. Average global solar radiation at flat surface

The potential surface [km²] that is "available" for installation of solar collectors is shown in the table below:

Total surface	Agricultural	Forests	Road and railroads	Water and other surfaces	Technically feasible
25713	3342	9888	99	488	11896

Installation capacity for solar collectors	33 MW/km²
Energy produced from solar collectors	46,71 GWh/km² year 4,02 ktoe/km² year
Technically feasible surface	11 896 km²
Total available solar energy	47 797 ktoe/ на 11 896 km² year.

The realistic potential available of energy can be estimated by the following approach. Above all, the surfaces in Macedonia are divided into two parts, in particular urban and rural:

Type of settlement	Total area [km^2]
Urban	15 660
Rural	9 253

Source: State Statistical Office

If we adopt the average coefficient of expansion of construction in urban settlements (0.07%) and in rural areas (0.02%), we estimate that the total area of constructed areas in Macedonia is 1 281 km^2. Therefore, if we assume that only 20% of the constructed area could be used to mount solar installations, we come to an area of 256 km^2 which can be used to estimate the cost-effective potential.

According to the data, solar energy bears the maximum share and wind energy the least. However, the share of wind energy in the electricity generation mix could increase with the development of the new technologies. Technology-wise, the new generation of bearings (MALEV) that enable electricity production at wind speed of lower than 1 m/s, compared to existing ones that demand wind speed of over 3 m/s, could increase wind electricity generation.

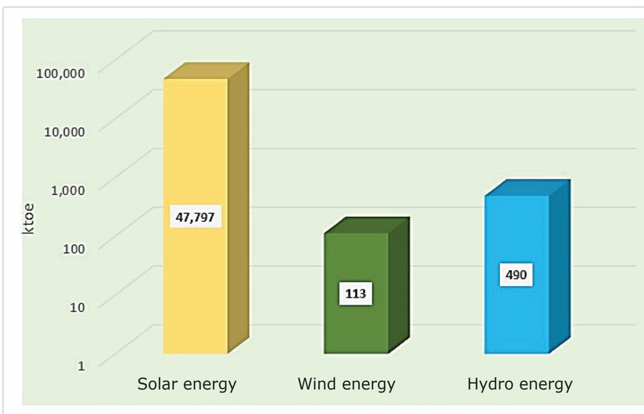
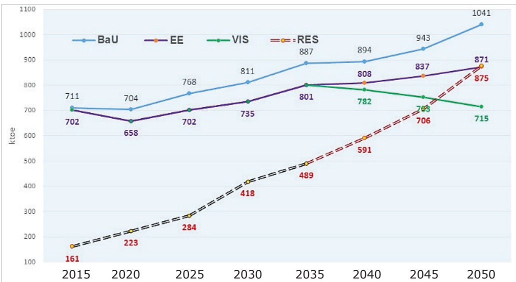


Figure 5.2. Technical potential for electricity production

Based on this data, we have derived a graphical representation of the dynamics of penetration of renewable energy resources into the electricity production sector.

One of the diagrams of Figure 5.3. shows the expected electricity consumption by 2050 for this purpose, as well as the dynamics of potential production of electricity from renewable energy resources.



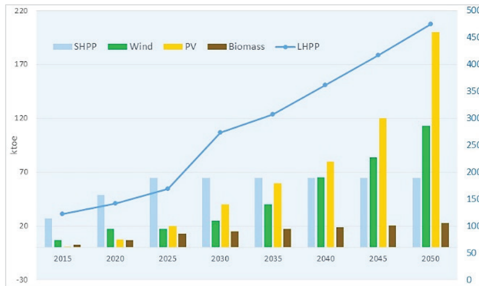


Figure 5.3. Required electricity and the expected production from renewable energy resources

In order to achieve these forecasts, we firstly assume that Macedonia will construct all hydropower plants as projected in the Strategy for Development of the Energy Sector until 2035. The same applies to the other power plants related to the sector of renewable energy sources.

However, in the upcoming period up to 2035 we must work on developing project documentation which will enable a favourable environment for intensive infrastructure investments into the large hydropower plants to ensure increased production of 1951 GWh, with wind power plants contributing 849 GWh and photovoltaic solar plants contributing 1,628 GWh.

To ensure the required production of electricity from solar collectors, in particular the amount of 200 ktoe in 2050, an installation of 1643 MW solar collector plants that spread over the area of 50 km^2 are required. It is also consistent with the Strategy that the solar collectors will generate 1416 kWh/m^2 per year.

The share of different renewable energy resources in meeting the electricity needs in 2050 is shown in Figure 5.4.

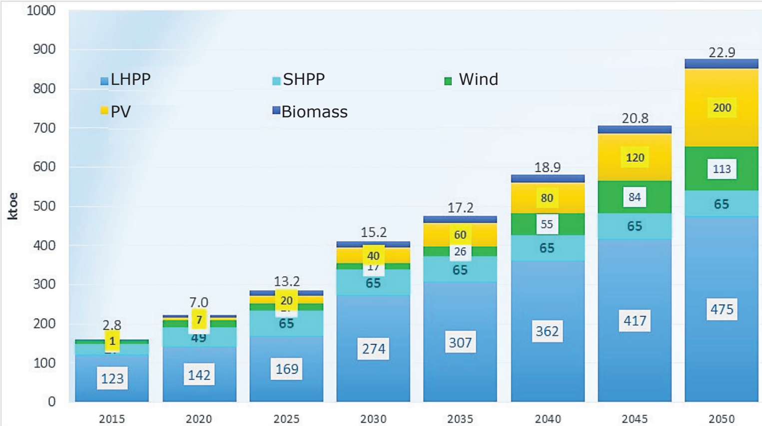


Figure 5.4. Dynamics and share of the renewable energy resources in the electricity generation

Biomass as fuel type has a 10 % share in the energy mix of Macedonia. The rationale is obvious since on the average 70% of households in Macedonia meet their heating needs with firewood, which is currently the cheapest fuel type used for this purpose. Moreover, the strategic documents do not anticipate broad biomass planting intended for the electricity production. However, this does not mean that there is no potential in the future to increase the production of electricity by increasing the use of digesters that would run on agricultural waste, or construct production plants to use synthetic gas from the process of biomass pyrolysis.

The following volumes show the technically available potential for energy production by utilisation of biomass (but here we mainly refer to the transformation in the form of thermal energy):

Biomass origin	Energy [GWh]
Biomass from agriculture	355
Biomass from stockbreeding	190
Biomass from forests	2362
Municipal waste	250

Source: Istraživanje i analiza tržišta za razvoj projekata obnovljivih izvora energije u zemljama regije jugoistočne Europe, Republika Makedonija, Energetski institut Hrvoje Požar; Centar za energetska efikasnost na Makedonija - MACEF, Skopje; svibanj 2015.

The current situation in Macedonia allows for the installation of 7MW plants that utilise biogas from bio digesters at a preferential tariff. The available quota is already taken by the installed plants of Veze Shari and the Agricultural Association Pelagonija. The quota of 10 MW for the installation of plants for the production of electricity from biomass by utilisation of the process of pyrolysis (or other process such as cogeneration) remains but is a subjected to limitations of firewood being an unsuitable fuel.

The operation of these plans contributes to an annual range of 70 to 90 GWh of electricity production.

Previous research established that Macedonia has a low temperature geothermal energy (hot water at temperature of 78°C) with a capacity of 390 GWh. The research was conducted at shallow dwellings (350-450 meters), but there are assumptions that the wells above 2,500 meters would have a geothermal potential for production of electricity.

At today‘s level of technical development, the investments in ORC power plants for electricity production that operate on geothermal water with a temperature of over 120°C are economically justified. It can be expected that in the future, certain technologies will be developed to enable the plants’ operation on fluids that would allow the transformation of heat into electricity at temperatures lower than 100^{o}C.

6. BARRIERS AND GAINS FROM THE DEVELOPMENT OF ELECTRICITY GENERATION FROM RENEWABLE ENERGY RESOURCES

Accomplishing the vision to ensure the production of electricity from its own domestic (renewable) energy sources, to stop imports of electricity and energy for production and to improve the living environment of citizens is not an easy and simple task.

The obstacles that need to be overcome in making this vision come true, while presenting a project and not a dream, are of different nature. Above all, they are of:

» Political nature
» Financial nature
» Technical nature

The obstacles of a political nature relate primarily to the interest of the political party in power to invest efforts and resources towards a vision that will be realised three or four decades later. The political parties are not familiar with such development programs and the major problem in promoting this vision is to change the mindset of the governing structures in the coming decades.

If the social consciousness „moves from ground zero‟ and civil society firmly supports this vision and its benefits, it will prevail over the short-sighted political (but pragmatic) programs. At that point, the vision turns into a development project with a „right to live‟ equally along with other short-term strategies and development programs.

For this reason, we believe that this is the first and main obstacle that must be overcome as soon as possible in order to continue focusing on the resolution of other obstacles. And if there is a will, a solution is inevitable. The problems of financial nature are very difficult to resolve and one could give up on this vision even before its realisation deeming these obstacles unmanageable. With correct long-term policy and investments in development programs within academic institutions, aimed at stimulating the creation of customised production bodies in sectors expecting long-term continuous investments, the level of the required investments may be reduced and may simultaneously lead to an increase in employment possibilities, profitability and the competitiveness of the organisations.

The problems of technical and organisational nature are not as tough and easy to resolve, arising from the manner of electricity generation from renewable energy sources. The main technical barrier in greater utilisation of RES in the power system comes from its stochastic manner of production. One cannot plan the production in advance and there have to be standby electricity producers whose production is not dependent on climate conditions.

The production of small hydro power plants depends on the hydrological conditions in any given year and is of rather seasonal character – higher production in spring, lowest in late summer and stopping during winter time.

The electricity production of solar thermal collectors is also closely dependent on outdoor climate conditions and is characterised by a 24 hour regime – day and night, is season related - summer and winter, as well as being dependent on climatic conditions such as clouds, fog or sunny days. Wind energy, even though not as closely dependent on the duration and the specific period of the day and night, has some seasonal characteristics and when possible, speaking from a macro perspective, one could expect a higher or lower electricity production. However, it's always connected to global climate change and local weather conditions which can seldom be predicted with accuracy. The following table shows the percentage of likelihood of wind, and thus the production of electricity for the site in Bogdanci:

Pinst=50 MW (50x1MW)	GWh	%
Winter	29,80	32,87
Spring	19,49	21,50
Summer	16,97	18,73
Autumn	24,39	26,90
Total	90,65	100,00

The probability of the various types of possible renewable sources for electricity production is shown in Figure 5.1., Production of electricity from renewable energy sources in 2015. Although the diagram applies to a period of only one year, it could be concluded that energy is more likely to occur in autumn and winter while solar energy is more likely to occur during the summer. In some ways, the maximum electric energy generation is deployed in phases or does not occur in the same period.

The hydro power plants with large accumulation capacity have the best performance by far in this group. They could be activated in a short period of time should unexpected situations occur with the other types of electricity generation plants. But the production capacity of accumulation hydropower plants is limited.

For this reason, there must be a very careful management system for the production and consumption of electricity. The basic production regime anticipates small hydropower plants and flow hydropower plants as well as maintenance of minimum water flows from reservoirs. The total generated energy from wind and solar power plants must be provided to grid intake. Hydropower plants should be used to cover variable loads of the grid and to cover the energy needs during the sunless and windless periods.

Apart from the problem of providing the power required when there is no sun, wind or enough water flow, there is an evident problem with the storage of the generated energy, that is not consumed at the time of its generation. This case is possible in the summer period, during high volumes of energy production from solar power plants and given low electricity consumption, for example, when industrial plants undergo refurbishment or during summer holidays.

The utilisation of accumulation devices/batteries for generated electricity storage of big capacities, at the current level of technical development, is still not completely economically feasible. It could be used for individual usage in a single house, for smaller capacity mobile plants such as automobiles or for the needs of certain production processes.

This problem could be mitigated or fully addressed by the construction of reversible hydropower plants, which use the excess generated electricity to pump the water to a higher level back into the dam.

The technical possibility for the generated electricity accumulation could be performed by water electrolysis and hydrogen production. The hydrogen could later be used for electricity generation in a common thermal power plant (as primary fuel) or in a contemporary power plant – fuel cells; a process in which higher coefficients of energy transformation into electricity could be achieved.

The problem of hydrogen transportation at greater distances (requirements for high pressure, low temperatures, penetration of small hydrogen atoms into the crystal net of the piping/ tank material structure) could be partially solved with ammonia production instead. Its transportation is financially more feasible and safe (explosion wise) – due to low pressure, common temperatures and more experience in usage of ammonia etc.

Furthermore, one of the main technical conditions for safe operation of the power system are a highly developed electro-transmission network, the interconnection with the neighbouring countries and the quality connectedness/inclusion in the European power system. Set in this manner, the system will support electricity exports (imports) at times of excess electricity production, and during shortages in production during times of higher demand for electricity intake from the system.

When a society is considering switching the whole economy to decarbonisation, there are other possible technical solutions, such as using the available excess electricity of heating tanks for hot water for central heating.

Also, one shouldn't overlook the possibility of and the potential for the construction of a nuclear power plant. Some of the primary risks, like the fear of a nuclear crisis could be expected to be minimised in the following decade. Meanwhile, we could expect new power plants to be offered on the market (following their experimental phase) that will be functioning on the principal of fusion of light atomic nuclei. TOKAMAK has been researched for a longer period of time in the laboratory/semi-industrial environment in Russia, while Switzerland (CERN) has commenced experimenting with the largest reactor of this type already.

The conclusion is that there will be hindrances along the way but they are manageable. The expected gains are huge and we shall commit to the possibility of moving forward.

7. ENVIRONMENTAL INFLUENCES

Environmental protection is increasingly becoming a hot topic, not only due to activism in this area but because it is also high on the agenda of politicians from leading countries. Everybody has become aware of the fact that the Earth is our common home and that everyone should care and keep the home safe for the generations to come within their powers.

The pollution caused by energy processes employing the combustion of fossil fuels has both global and local character. The global character refers to everybody's pollution anywhere and which, as a consequence, causes climate change. The mechanism is evident - during the process of fossil fuel combustion, carbon is released and it further binds with oxygen to form carbon dioxide CO_2, which causes the greenhouse effect and global warming on the planet.

Local pollution has considerably more serious and tangible consequences compared to the global one. Moreover, main pollutants are the solid particles (ash and coke), sulfur dioxide, which causes acid rains and degradation of the quality of soil and forests, as well as nitrogen oxides. It should be communicated that coal and crude oil both contribute considerably to local pollution compared with natural gas. They affect the quality of air and are causing a range of diseases to the respiratory organs, especially in children.

It should also be mentioned that there is pollution coming from soil, which has to be removed to reach coal and is generated during the process of the exploitation of surface mines and large dumpsites of slag and ashes. Despite the fact that the levels of radioactivity in the waste are relatively low, a number of studies in Macedonia show that they cannot be underestimated.

What will it mean for Macedonia if no more coal is utilised to produce electricity? It would mean that on average 7 million tons of coal will not be combusted on an annual basis. Furthermore, that it will prevent emissions as in the case of REK Bitola:

Parameter	Dimension	Chimney A1 (medium/max)	Chimney A2	Total
CO	t/year	312/554	68/160	380/741
SO_2	t/year	36,367/54,783	20,675/30,590	57,042/85,373
NO_x	t/year	7,266/10,316	3,749/4,814	11,015/15,130
CO_2	t/year	3,217,904/4, 365,038	1,710,155/ 1, 917,173	4,928,059/6, 282,211
Dust		4,802/11,711	2,271/ 3,880	7,073/15,591

Source: Application for acquiring A-License for association with the operational plan, ELEM- Subsidy REK Bitola, 2007

In summary, REK Bitola and TPP Oslomej contribute to environmental pollution by the following:

- over 6.3 million tonnes CO_2 each year
- over 85 000 tones SO_2
- over 15 600 tones dust released in the air.

Although these figures are small compared with the emission of harmful substances by industrialised countries, they are very large for our local and immediate environment.

If we take into account the potential electrical powered cars offer, besides recharging their batteries during periods of greater production of electricity from renewable energy sources, there would also be a significant reduction of pollution in urban areas caused by the reduced combustion of fossil fuels in the transport sector.

8. INVESTMENTS

Would the realisation of this vision be cheap? No. Huge investments are required. Without going into details of the financial projection i.e. the "Business plan", a simple comparative technical-economic projection shows that investing in electricity generation from renewable energy sources is economically justified when we analyse the entire life cycle of the plant.

We prepared a comparison between the total cost of investment in a coal-run power plant, a mine and a photovoltaic power plant, given an equal amount of annual electricity production. We underline that the case features identical energy production, because the coal thermal power plants' standard operation equals 6,000 hours per year under the nominal installed capacity, while the solar plant „operates" only 1400 hours per year under its installed nominal capacity.

The comparison was done by comparing the following conditions:

Conventional Thermal Power Plant on Coal with a Mine

Installed capacity of a coal thermal power plant	200 MW
Annual operation hours per installed capacity	6000 h/year
Generated electricity capacity	1200 GWh/year
Specific plant investment	1800 €/kW
Total thermal power plant investment	360 M €
Fuel price (coal)	20 €/t
Price of the coal energy values	9 €/MWh
Thermal value of the coal	8000 kJ/kg
Coal consumption per generated 1 kWh electricity	1,35 kg/kWh
Required coal quantity for electricity production	1620 k t/ year
Annual fuel costs	32 M€/ year
Lifecycle of the plant	40 years
Fuel costs for 40 years operations	1296 M€
Total investment and fuel costs for 40 years of operation	1656 M€

Photovoltaic Collectors' Solar Power Plant

Rate of working hours for using the TEC/ PV	4,29
Annual operation hours per installed capacity	1400h/year
Required installed capacity of the PV plant	857 MW
Generated electricity capacity	**1200 GWh/year**
Specific plant investment	1000 €/kW
Total solar power plant investment	857,14 M €
Fuel price	0 €/t
Average space of the system	2,8 ha/MW
Total space for construction of the solar power plant	24 km^2
Lifecycle of the plant	40 years
Total investment and fuel costs for 40 years of operation	857 M€

If it is accepted that the average selling price of electricity by the manufacturer is 40 €/MWh, a total of 1920 M€ will be collected from both facilities. There is an evident difference between these two projects: a 2.4 times higher investment is required at the beginning of the solar plant construction, but its financial gains are about 4 times larger given the operation period.

The cost and profit trends at these initial conditions are shown below in Figure 8.1.

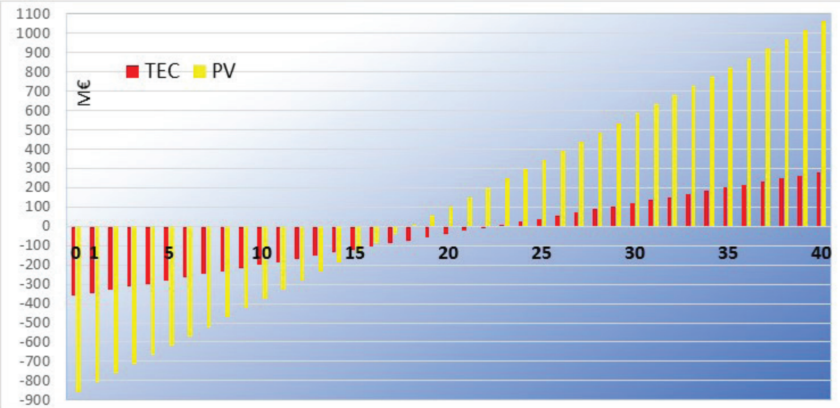


Figure 8.1. Financial trends during the plant operation period

The ratio between required investments for the construction of different types of plants is provided on the basis of macroeconomic parameters. Also, depending on the average period of operation of different types of renewable energy sources, the required installed capacity to produce an identical amount of energy as in the fossil fuel plants has been estimated. This estimation is not suitable for the large accumulation hydropower plants; however, their main design parameters were taken into account.

	Unit	TPP	Sun	Wind	SHPP	Chebren	Galiste
Capacity	MW	200	857	545	456	333	193.5
Specific Investment	M€/MW	1800	1000	1500	2200	956	1033
The use of installed capacity	h/year	6000	1400	2200	2630	2360	1354
Total Investment	M€	360	857	817.5	1004	319	200
Annual generated power	GWh/year	1200	1200	1200	1200	786	262
Ratio investment/ annual production	M€/GWh	0.300	0.714	0.681	0.837	0.406	0.763

It is clear that it takes several times higher investments to build power plants that use renewable energy sources. Moreover, it should be emphasised that once these facilities are constructed, there is no spending on fuel (liquid and gaseous fuels, quality coal), nor any costs for domestic mining of low-quality (lignite) coal.

The number of employees required to realise the production process or investments in regular maintenance of equipment are not the subject of this analysis. If we take these elements into account, economic viability of utilisation of renewable energy sources in electricity production will increase further.

9. CONCLUSION

The basic conclusion of the authors is that Macedonia has sufficient renewable energy resources at its disposal to fully meet the needs for electricity generation without utilisation of fossil fuels.

The realisation of this goal is possible but it is neither easy nor simple or cheap. However, the sooner this message gets to the consciousness of the decision makers the sooner society would take a step forward towards a cleaner and more energy secure future.

The promotion of this possibility will allow for a serious approach and the development of an environment that will enable this vision to come true.

This vision is not utopia!

It should be developed into a project and then become a part of the strategic development documents of the Country.

The construction of the new plants will require big capital investments but it will also create many new jobs. The period is sufficient to achieve a phase-by-phase training of a sufficient number of qualified staff, as well as to retrain employees in sectors that will slowly disappear.

It is especially important that the State intentionally stimulates the development of organisations to produce the necessary equipment on their own. In cases of large orders meeting increased market needs, the final price of the equipment will become more acceptable.

This will be a major challenge for the development of scientific research bodies, which will certainly join the production organisations as their consisting part.

The fact that people are going to step forward towards a decarbonised world is a reality. However, it depends on whether we will be among the first to create this social awareness or remain lagging behind.

It is our own choice!

We are making the choice on behalf of the next generations!

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ABOUT THE AUTHORS

Prof. PhD Konstantin Dimitrov, an award winning inventor, is a scholar and researcher with over 470 published works ranging from scientific projects, studies, research papers both in the country and abroad and has projects with a high rate of implementation success, expert works, diagnostic research, expert audits and text books. He was teaching professor at the universities in Skopje, Bitola and Pristine and lectured at specialization courses in quite a few countries such as Greece, Bulgaria, Romania, Turkey, the USA and Germany. Dimitrov has participated in the preparation of strategic, policy and legal documents of national importance in the energy sector, such as the Strategy for the Energy Sector by 2030, the Strategy for Energy Efficiency and the 1st, 2nd and the 3rd National Action Plan for Energy Efficiency. Awards: National Award – Patent of the Year 1998; "EUREKA 98" – Brussels, Golden Award; Special Award of the Academy of Sciences 'Marconi', Italy; Special Award from the Ministry of industry and transport, Belgium. Dimitrov holds the post of General Secretary of the Association of Thermal Engineers of Yugoslavia, is President of ZEMAK and since 2002 Founder and President of MACEF.

MSc. Ass. Ognen Dimitrov, graduated from the Faculty of Mechanical Engineering – Skopje. Since 2000 he has been employed at the laboratory for processing machines as part of the Department for Thermo-technology and Thermo-energy. He holds authorization for design, audit and supervision of the mechanical related phases of the construction stage. In 2004, he graduated with a Masters degree in the energy sector from the Faculty of Mechanical Engineering – Skopje. He has published and presented over 35 research papers and expert works both in the country and abroad. He joined the Energy Agency of the Republic of Macedonia in 2007, where he also represented Macedonia in an international project at UNCEE, Geneva. At the same time, he has been elected as assistant lecturer at the University American College, Skopje, and taught the course "Sustainable Development and Environment". In 2010, Dimitrov joined the GIZ project (German Association for Technical Cooperation in RM) in the City of Skopje. The project resulted in the establishment of an Info Centre for Energy Efficiency and Renewables in the City of Skopje. His daily tasks are related to gasification processes, public procurement, contracting, supervision and construction of gas plants in public facilities under the authorization of the City of Skopje. He is one of the founders of MACEF and Management Board President.

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